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ABSTRACT

This digest addresses the issue of sex differences in mathematics achievement in K-12 students. The problem is discussed in three sections. The first section examines the progress that has been made in narrowing the gap between girls' and boys' achievement in mathematics and the numbers of women and men who enter mathematics-related careers. Issues addressed include the failure of research to find any inherent differences in girls' and boys' abilities in mathematics, the underrepresentation of women in mathematics-related fields, strategies to motivate girls to take more mathematics courses, and strategies to encourage girls to consider mathematical and scientific careers. The second section offers innovative approaches in mathematics education funded by the Women's Educational Equity Act (WEEA) Project. A list of the products mentioned in the article is provided. The third section discusses a vision of reform from the Urban Mathematics Collaboratives (UMC) that seeks to increase mathematics equity in the classroom. UMC offers a view of equity embodied in six propositions involving: (1) high achievement and high expectations; (2) student access to rich mathematical content; (3) student assessment and equity; (4) teachers' professional development in equity issues; (5) teachers' professional development in mathematics curriculum and instruction; and (6) school restructuring and equity. (MDH)

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WOMEN'S EDUCATIONAL EQUITY ACT PUBLISHING CENTER

DIGEST

Education Development Center, Inc.
OERI, U.S. Department of Education

Girls and Math

Enough Is Known for Action

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Girls are taking almost the same number of math courses as boys (2.9 vs. 3.0) however they are less apt to take Trig or Calculus.

In 1979 women accounted for 9% of the science and engineering work force; in 1988 that increased to 16%. However women are 45% of the total work force.
—National Science Board

In the last 15 years, many things have changed with regard to girls and math. While boys still outnumber girls in upper-level math, girls are no longer uncommon. And while women are not entering careers that need math in numbers equal to men, neither are women a rarity in these fields. At all levels there has been increased awareness of the underrepresentation of women in math, science, and engineering and what this could mean for the country, as well as for individual women. Calling it an issue of "paramount concern," former National Science Foundation director Erich Block urged Americans to look to underrepresented minorities and women to meet the growing demand for scientists and engineers in the United States.[1]

Society's perception of women and math is changing, albeit slowly. Television scenes of mothers telling children to wait for their father for help with math homework because the mothers were "never any good at math" are being matched by scenes such as the November 1990 "Evening Shade" where the father tells his daughter to wait until her mother gets home to get help with math homework because the mother is so much better in math. Even in the movies, women who can't balance their checkbooks are being replaced by women such as the wife in *Presumed Innocent* who had a Ph.D. in math and a husband who had loved her helping him through algebra. Of course, she was the murderer, but . . .

Thanks to research, we now know that sex differences in math achievement are small and declining.

"Math gap" narrows

During the past few years, there has been an explosion of research on girls and boys and math. Thanks to research, we now know that *sex differences in math achievement are small and declining.*

Analysis across hundreds of studies has found that in the general population women and girls outperform men and boys in math by a very small amount. Females score slightly higher in computation, males slightly higher in complex problem solving, and there are no differences in math concepts.

There are no sex differences in problem solving until high school, when differences favoring males occur. Greater male superiority in math achievement shows up in more academically selective populations.

Analysis of studies done before and after 1974 has found sex differences declining over the years to negligible levels. While women still lag behind in some aspects of spatial abilities and in math achievement at the top levels of mathematics, they are gaining on men in mathematics as a whole.[2]

Research has also identified at least one of the reasons that boys show more

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interest in math. *Boys in math classes tend to receive more teacher time and attention than girls.* Teachers have been found to give boys more praise, more criticism, more remediation, and to be more apt to accept boys' responses. They also respond more frequently to boys' requests for help and talk to boys more about ideas and concepts.[3] Boys are much more apt than girls to be in the small group of students who receive most of the teacher's academic time and interest and to receive more encouragement from their parents to take advanced math.[4]

Giving more attention and resources to boys is so much the norm that teachers who try to give equal attention to girls often feel uncomfortable because they feel the boys are being slighted.[5]

Boys in math classes tend to receive more teacher time and attention than girls.

Questioning a "math gene"

The great preponderance of evidence indicates there is no "math gene." Sex differences in mathematics achievement have become small enough in most areas to be considered negligible. While society may change fast enough for this to happen, biology doesn't. Genetic differences tend to remain stable, but sex differences in mathematics achievement are decreasing.

Sex differences in such traditionally "masculine" areas as spatial relations have been eliminated by changing teaching practices and providing both girls and boys with opportunities to build their skills.[6] Practice can improve many things, but not genes.

The finding that gifted seventh-grade boys are much more likely than girls to score highly on the SAT: Math is often used to justify a biological basis to math sex differences. However, this reasoning is seriously flawed. Fundamental errors occur when researchers "assume that because girls and boys have been in the same math ,classes they have had the same experiences, assume that differences on SAT, a test the courts have found to be biased against women, are biological, assume that gifted children whose parents pay over $30 for their children to take a test represent the population as a whole, [and] tell girls and boys *before* they take the SAT that girls don't do as well as boys!"[7]

In earlier ages, it was believed that women could not pursue mathematics because their heads were too small, their nervous systems too delicate, or their reasoning capacities insufficient. Even such an eminent educational theorist as Rousseau believed that women were not qualified for research in abstract areas such as mathematics and science because their brains were unfit. While such notions are clearly passé, they do have twentieth-century counterparts.[8]

Changing the question

The question we should be asking is not "Is there a math gene?" but rather "Why are there so many fewer women than men in math-related fields, when the sex differences are so small?"

We have been successful in encouraging middle-class girls in math and science at the precollege level, but we have not been as successful at the college level where young women enter math and science fields at much lower rates than young men and also drop out of math and science majors in greater numbers than do similarly talented young men with the same grades.[9]

We have also not been successful in encouraging low-income girls and girls of color in math and science even at the precollege level. And math is still a critical filter. Low-income students and students of color who take algebra and geometry go to college in numbers equal to wealthier whites. However, only half as many low-income students and students of color take these important courses.[10]

Where to start

The irony is that we know what to do. Based on research and evaluation we know how to get girls to take more math and science.[11] Here are some of the strategies that we know work.

Intervene in seventh and eighth grades. In most schools, students decide in eighth grade if they will take algebra, an important first step to continued math involvement. After being in a program with activities showing that algebra can be fun, and being encouraged that they could do math, one group of low-income, urban, Hispanic girls all decided to take algebra.[12]

Intervene in ninth and tenth grades. Sophomore year is another key decision-making time. While girls and boys are equally apt to take algebra and geometry, girls are more likely than boys to stop there and take no more math.[13]

Design programs and math classes that incorporate what girls feel they are currently missing in much "school math." Girls decide to take more math and science (and continue taking the courses) after participating in math sessions they see as more fun, more relaxed, with less pressure and less competition, with more hands-on work and problem solving, and with teachers who explain more and answer questions, "making sure you understand."[14]

The question we should be asking is not "Is there a math gene?" but rather "Why are there so many fewer women than men in math-related fields, when the sex differences are so small?"

The career question

We also know some successful strategies to get girls to consider math and science careers.

Get girls beyond the "nerd" factor. Stereotypes about people who are good in math and science are still a problem. Informal social sessions with adult scientists have been shown to change high school girls' views of people who are good in math and science from "nerdy" and "strange" to people who are social and have a sense of humor. This holds for both white girls and girls of color.[15]

Emphasize career exposure, not career choice. Sessions on selecting a career for high school and middle school students don't seem to work in encouraging girls to choose math- or science-related careers. However, talking with scientists and engineers about their work has caused girls in several programs to consider those careers for

themselves.[16]

Involve girls in activities that reflect the work of people in different science and math careers. Participating in hands-on engineering activities made girls in one program *six times* more likely to consider engineering as a career.[17]

Reduce the isolation frequently felt by girls who are already interested in math and science. Scheduling time for girls to "just talk" to each other has helped them find out that there are "girls just like me" who "have the same problems [of being a 'smart' girl in math and science]." Where follow-up is done, it has been found that most of the girls continue to keep in touch and provide each other with an ongoing support structure.[18]

Challenges ahead

While there is much we know, we have several important challenges left to face.

How do we institutionalize effective programs? Programs to encourage girls in math and science are "dependent on the kindness [or at least the funding] of strangers." Effective programs need to become institutionalized, to become budget items of the organizations that have hosted them for so long.

How do we reach large numbers of teachers? There will never be enough programs to reach all students who need them. Yet many of the characteristics of effective programs—more hands-on and fun work, less individual competition—can and should become a part of math and science classes.

How do we move away from the syndrome of "them that has, gets"? Most programs and classes are for boys and girls. Yet in coed settings—even those incorporating gender equity—boys tend to get the lion's share of attention and opportunities. Indeed, at the end of one gender-equity effort, teachers listed fewer girls as interested in science than they listed before the program started! We must learn how to make special programs special for all.

Researchers and practitioners, scholars and activists need to join together, to share what we know and to learn from each other. Those whose major interest is in equity must be involved in math reform efforts to ensure that these efforts are equitable, and those whose major interest is in math reform must be involved in equity efforts to ensure that these efforts are effective.

As Paul Tsongas reminds us, "Equal opportunity, we have learned, is more than an open gate. It is the appropriate complement of skills and fundamental self-esteem that makes the open gate meaningful. To just open the gate is to engage in a cruel gesture, no matter how innocently it is done."[19]

The gate is opening, much of the knowledge is there. It is up to us whether girls are offered a real chance or just a cruel gesture.

Patricia B. Campbell, Ph.D.
Campbell-Kibler Associates

For further reading on Dr. Campbell's research, see her article "So What Do We Do with the Poor, Non-White Female? Issues of Gender, Race, and Social Class in Mathematics and Equity," in Peabody Journal of Education *(vol. 66, no. 2 [dated Winter 1989; forthcoming 1991]).*

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WEEA offers innovative approaches to math

Over the last 15 years the Women's Educational Equity Act (WEEA) Program has funded a number of projects that have addressed the issues surrounding females and the study of math. The WEEA Publishing Center carries many innovative and proven curricula developed by these projects.

The publishing center's latest publication, *Add-Ventures for Girls: Building Math Confidence*, combines teacher development and empowerment with the strategies that we know work in teaching girls. Called "a major breakthrough in creating a more equitable mathematics environment," this teacher-developed program educates teachers on issues related to girls and math—attitudes, making math relevant, the learning environment, computers, test-taking skills, and more—and then presents specific strategies and activities that address these issues.

Add-Ventures for Girls is available in two volumes, one for elementary teachers and one for middle school teachers, thereby helping girls get a good start in math. Sections in both volumes help teachers plan practical steps to involve parents, school counselors, administrators, and other teachers in encouraging math for girls.

Newly developed through a 1989 WEEA grant is a series of brochures by Dr. Patricia Campbell that highlight her latest research on effective strategies for encouraging girls in math, science, and engineering. The brochures are aimed at different groups, including parents, teachers, and program administrators. They translate research into practical strategies for designing effective programs, for evaluating programs, for collaboration between schools and outside programs, and for helping parents to encourage their girls in math and science.

A new curriculum entitled *Science EQUALS Success* contains over 30 activities that utilize approaches identified by the nationally recognized EQUALS Program as being particularly successful with girls. These activities are designed for girls in grades 4–9, and work to interest and motivate girls during one of the critical periods when many lose interest in math and science.

A number of WEEA products address specific issues in teaching and learning math. *Spatial Encounters* is a self-directed program for all ages that helps students develop and practice spatial visualization and orientation skills—tools that help students in classes such as geometry and that are necessary in many math- and science-related professions.

One of the recommended strategies for making math relevant for girls is to discuss career options in math- and science-related fields. A number of WEEA products do this, in ways that appeal particularly to girls. Some of these books include *Expanding Your Horizons in Science and Mathematics; How High the Sky? How Far the Moon? An Educational Program for Girls and Women in Math and Science;* and *The Sky's the Limit in Math-Related Careers.* And two handbooks are targeted toward adult women: *Beating the Numbers: A Woman's Math Careers Program Handbook* and *Science, Sex, and Society.*

Math anxiety is a common reason some female students have trouble in mathematics courses. *A Mindset for Math: Techniques for Identifying and Working with Math-Anxious Girls* helps teachers reduce math anxiety among upper elementary and middle school students. And *Developing Math Learning Skills: A Parallel Support Course for the Math-Anxious Student* helps adult students or program participants develop successful strategies for learning and enjoying mathematics.

Listed below are the products mentioned in this article. All were developed with funds from the Women's Educational Equity Act Program and are available from the WEEA Publishing Center, unless otherwise noted. The WEEA Publishing Center materials may be purchased by mailing a check or money order for the amount of the order (plus $2 shipping for orders under $25; $4 for orders $25 and over) to the WEEA Publishing Center. To order by phone, using MasterCard, Visa, or purchase orders over $25, or for information on additional resources available through the WEEA Publishing Center, call 800-225-3088 (in Massachusetts call 617-969-7100).

Add-Ventures for Girls: Building Math Confidence, by the Research and Planning Center, University of Nevada
Volumes for elementary school teachers and middle school teachers use fun, hands-on activities that incorporate strategies and approaches particularly effective with girls. ***(#2709 elementary school volume $25.00; #2710 middle school volume $28.00)***

"Nothing Can Stop Us Now: Designing Effective Programs for Girls in Math, Science and Engineering"
"Working Together, Making Changes: Working in and out of School to Encourage Girls in Math and Science"
"What Works and What Doesn't: Ways to Evaluate Programs for Girls in Math, Science, and Engineering"
"Math, Science, and Your Daughter: What Can Parents Do?" by Patricia Campbell, Campbell-Kibler Associates
These four brochures target different audiences with results of the latest research on what works in math and science programming for girls. Highly readable and strategy oriented. All are available from Campbell-Kibler Associates, Groton Ridge Heights, Groton, MA 01450.

Science EQUALS Success, by Charlotte EQUALS
Contains over 30 hands-on, discovery-oriented science activities designed especially for girls and students of color in grades 4–9. The activities incorporate problem solving, cooperative learning, spatial skills, and career awareness, processes recommended by the EQUALS Program. A collaborative effort of the University of North Carolina—Charlotte, the Charlotte-Mecklenburg School System, and the Science Museums of Charlotte, Inc. ***(#2711 $16.00)***

Spatial Encounters, by the Institute for Applied Research Services, University of New Mexico—Albuquerque
Exercises in spatial awareness that combine fun and learning. The activities include memorization of shapes, figure completion, and figure rotation and emphasize real world applications. For K–12 and adults. ***(#2434 $27.00)***

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Math equity in the classroom

A vision of reform from the Urban Mathematics Collaboratives

As the nation moves closer to the year 2000 and to a new vision of education under the National Education Goals, academics, researchers, and classroom teachers are looking at ways in which to both examine and rectify inequities in mathematics instruction. Some, like Elizabeth Fennema at the University of Wisconsin are exploring the development of cognitively based instruction as a way to increase equity in the teaching and learning of mathematics. Others, like the Family Math Program at Berkeley, work directly in communities and schools to introduce new approaches to teaching.

And, beyond this is the development of new discussions around gender, race, language, or ethnic differentiation within mathematics education. Although Fennema's work is one attempt to create an education model that focuses on cognitive rather than affective issues, very little has yet been done to explore what is happening in terms of perceived or actual equity within mathematics classrooms. For instance, even within mathematics software development, many developers have admitted that in their focus on creating good software, they have not yet begun to look at the issues of gender differentiation as they apply to the use of their models.

Some groundwork for such an exploration of gender and race differentiation within mathematics instruction has been set by discussions within the Urban Mathematics Collaboratives (UMC). This Ford Foundation–funded effort to improve mathematics instruction around the country currently supports collaboratives in 14 cities. UMC teachers, who work across the spectrum of K–12 mathematics education in urban schools, have had to deal directly with issues of equity since their students reflect the racial, ethnic, and linguistic diversity of our cities. Together with the UMC Outreach Project at EDC, UMC teachers have drafted a strong policy statement on equity in mathematics education that can serve as a guide for all educators. We quote here from that statement as one approach to reform in mathematics education that can provide a basis for dialogue.

The paper recognizes that "until recently, the United States had been able to meet its needs for a mathematically trained workforce by providing advanced study for a small, elite segment of its school population, typically Anglo and male. In part, too, however, the causes [of inequity] lay with mathematics education and with the disjuncture between schools and the lives of their students. Mathematics curriculum, textbooks, and instruction often failed to speak to the lives and concerns of females and other underrepresented groups. Consequently, these groups were cut off from real opportunities for success in mathematics."

"The principal objective and desired outcome of . . . mathematics teaching and learning is the high achievement of all students."

The UMC statement also recognizes that the kinds of changes that must be made cannot be made by teachers alone. "The success of mathematics teachers depends, in part, on the commitment of others with a stake in mathematics education—students, parents, representatives of business and industry, textbook and test publishers, university faculty in mathematics and mathematics education, and district administrators responsible for mathematics programs." Together these groups can begin to solve the inequity in mathematics learning. For those who believe that mathematics programs must serve all students as a means of ensuring equal opportunity and strengthening the nation's social and economic institutions, UMC offers a view of equity embodied in six propositions.

"1. *High achievement/high expectations.* The principal objective and desired outcome of . . . mathematics teaching and learning is the high achievement of all students, especially those who have been underrepresented in advanced mathematics study and mathematically based careers. Mathematics instruction must reflect the assumption that all students can succeed in learning mathematics. Mathematics teachers must have high expectations for the success of each student, and classroom experiences must be structured in such a way that students gain confidence in their ability to do mathematics. Mathematics instruction must be tailored to the particular learning needs of students, and teachers must embrace the racial, ethnic, and linguistic diversity of the student population as a valuable resource for their teaching. . . .

"2. *Student access to rich mathematical content.* . . . By 'rich' mathematical content we mean rich in mathematical concepts, rich in applications and connections to students' social settings, and rich in perspectives and values that reflect students' cultural heritages. . . .

"3. *Student assessment and equity.* . . . Schools must abandon their excessive reliance on standardized, multiple-choice tests as the principal measure of student achievement. Too often, results from these tests are inappropriately used to assign students to tracks or ability groups, condemning many capable but low-scoring students to a devastating cycle of remediation. Teachers must have opportunities to develop and use new forms of assessment—hands on demonstrations, portfolios, open-ended questions, and student-generated tests—that are directly linked to student performance and that reinforce student learning rather than inhibit it. . . .

"4. *Teachers' professional development: Issues of equity.* Mathematics teachers in urban communities will need special preparation and ongoing support to address issues of inequity and to accommodate the learning needs of an increasingly diverse student population. . . . It is important that urban mathematics teachers be afforded meaningful opportunities to understand

Continued on page 6

Math equity . . . continued

[the needs of their students] and to learn about effective methods [of teaching]. Equity must become a dominant theme of preservice and inservice mathematics education. . . .

"5. *Teachers' professional development: Mathematics curriculum and instruction.* Mathematics teachers who work in urban schools must have access to a broad spectrum of professional development opportunities in their subject areas. Providing all students with equal access to mathematics instruction will be a false promise if the curriculum itself is outdated or irrelevant. . . . Intellectual renewal, lifelong learning, and active engagement with colleagues are all part of teachers' professional lives. . . .

"6. *School restructuring and equity.* School restructuring is essential for achieving greater equity in mathematics education. Teachers must have greater freedom in making curricular and instructional decisions, in organizing the school day, in determining student assignment, in allocating resources, and in structuring professional development opportunities if they are to meet the individual learning needs of all students."

For a copy of the complete UMC policy statement, or for information on other equity work going on in mathematics and science, contact the WEEA Publishing Center.

Katherine Hanson
Education Development Center

WEEA's innovative approaches . . . continued

Expanding Your Horizons in Science and Mathematics, by Joanne Koltnow, Mills College
A handbook that tells educators and parents how to plan, conduct, and evaluate conferences for young women who have an interest in math and science. An accompanying videotape, *Sandra, Zella, Dee and Claire,* takes a look at the careers of four women—an astronomer, a veterinarian, a laser physicist, and an engineer. ***(#2078 handbook $8.00; #2655 VHS video purchase $43.00; #2656 VHS video rental $7.00)***

How High the Sky? How Far the Moon? An Educational Program for Girls and Women in Math and Science, by Sharon Menard
A comprehensive program for teaching science and equity at the same time. For grades K–12, lessons are arranged by grade levels and contain lesson plans and materials. ***(#2104 $13.50)***

The Sky's the Limit in Math-Related Careers, by Judy Askew, Mills College
In this informative handbook, women working in computer science, engineering, finance, and other math-related fields offer lively anecdotes, viewpoints, and inside information about their careers. For high school students. ***(#2237 $6.75)***

Beating the Numbers: A Woman's Math Careers Program Handbook, by Boston Math Careers for Urban Women
A detailed handbook for planning and delivering a 16-week program for high school graduates or GED students who need improved math confidence and skills to further their careers. Discrete modules are geared to specific industries. ***(#2222 $14.25)***

Science, Sex, and Society, by Ann E. Kammer, Cherlyn S. Granrose, and Jan B. Sloan, Kansas State University
A college-level anthology designed to help young women make knowledgeable choices about careers in science. Extensive bibliographies and career counseling resources will help science professors design a challenging introductory course. ***(#2144 $28.00)***

A Mindset for Math: Techniques for Identifying and Working with Math-Anxious Girls, by Ohio State University
A program for upper elementary and middle school students that treats anxiety as a component of math instruction. Helps girls recognize feelings of anxiety and learn to reduce them, using proven stress-reduction techniques. Activities make math relevant and fun. ***(#2681 $10.75)***

Developing Math Learning Skills: A Parallel Support Course for the Math-Anxious Student, by New Mexico State University—Las Cruces
A comprehensive program for helping women at college level or in adult programs—including teacher training—work through psychological and knowledge-based barriers to enjoy and understand mathematics. Participants in this program have had documented increases in arithmetic and algebra scores. ***(2702 $6.75)***

WEEA Monographs
Monographs present in-depth discussions on cutting-edge issues in gender equity.
2744 Teaching Mathematics Effectively and Equitably to Females $4.00
2745 Building Self: Adolescent Girls and Self-Esteem $4.00

Women's Educational Equity Act Publishing Center
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55 Chapel St., Newton, MA 02160
800-225-3088/617-969-7100

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